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The Model of the Earth's Magnetic Environment (MEME) [1] is an important tool for calculating the earth's magnetic field. In addition to being used directly for scientific study, this model is also a building block for a number of other BGS codes which have a wide variety of applications from oil and gas exploration to GPS positioning.

The Earth's internal magnetic field is generated by the motion of the conductive metallic fluid in the outer core. Changes in the motion of this fluid, which are happening all the time, cause variations of the shape and intensity of the magnetic field measured at the surface. In order to calculate the current magnetic environment, the MEME models uses a combination of current and historical data from magnetic survey satellites (such as the ESA Swarm mission) and observational sites around the globe.

Computationally the model requires the solving of differential equations which it does by calculating Eigenvalues and Eigenvectors of a matrix (built from the input data) via the GOLUB algorithm, where the matrix is tri-diagonalised using Givens rotations. This method is very stable, but neither fast nor parallelised. The small amount of parallelism already present in the code is used for building the matrix, which itself is very time consuming, and exhibits significant load imbalance. Due to the sequential nature of the solver all data must fit within a single memory space and this is currently a major limitation. Due to these memory issues the model is limited to around 10,000 parameters and this means that only a subset (often 1 in 20 points) of current satellite data can be studied. With the deployment of new observation satellites and technologies imminent, it is realistic that runs with over 100,000 parameters will be required in the future but this is far beyond what the model is currently capable of.

We have replaced the bespoke solver with the SLEPc [2] package which builds upon PETSc to provide Eigensolvers. There are two advantages to this; firstly we get numerous solvers *out of the box* which are trivial to swap in and out so we can experiment with performance and stability. Secondly we are able to leverage the existing PETSc parallelism mechanisms.

SLEPc/PETSc favours decomposing the matrix in a row based fashion where a number of matrix rows reside on each processes. However this raises a challenge when building up the matrix due to the symmetry. If we niavely built the matrix then it would result in a very uneven load (depending upon the number of points a process has in the upper part of the matrix) or a duplication of calculations. To address this we have developed an algorithm which evenly distributes the points in the matrix for building by including a subset of points in both the upper and lower parts of the matrix. Whilst some communication is required once building has been completed, the work is well balanced and hence far more efficient than the existing approach, inherently works with the distributed data we require and extra parallelism is possible by utilising multiple processes in the building of each row.

In this talk we will discuss our work modernising the solver and parallelism of this model, the suitability of SLEPc and our algorithm for balancing the matrix building. We will illustrate the performance and scalability of the new code on ARCHER and describe the process adopted for providing confidence in the accuracy of results (which is very important to the community.)

References

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